"Marked Up" Versions of the Amended Paragraphs

Paragraph beginning at page 4, line 14.

~~To determine the distance between the template and the substrate, the method may include obtaining data representative of the intensity of at least some of the wavelengths of light reflected. A wavenumber may be calculated based on the data, where the wavenumber is a function of the refractive index of a material disposed between the template and the substrate and the wavelength of the refractive light. The distance between the template and the substrate may then be calculated. The distance between the template and the substrate may be a function of the wavenumber and the intensity of reflected light corresponding to the wavenumber. Calculating the distance between the template and the substrate may include determining a Fourier Transform of the wavenumber and intensity data. In some instances, the method may also include determining at least one local maximum or local minimum of the data after performing the Fourier Transform.~~

Paragraph beginning at page 7, line 29.

A system for forming a pattern on a substrate using a template may include, but is not limited to:

a top frame;

an orientation stage coupled to the top frame;

a substrate stage below the orientation stage configured to support the substrate; and

a light based measurement device coupled to the ~~orientation stage~~<u>top frame</u>.

The orientation stage may include a template support. A template may be disposed in the template support. The light based measurement device may be configured to determine a distance between the template and the substrate. Additionally, one or more fluid dispensers may be coupled to the top frame.

Paragraph beginning at page 8, line 19.

In certain embodiments, the first flexure member may include first and second arms. The first arm may include a first set of flexure joints configured to provide pivotal motion of the first flexure member about the first orientation axis. The second arm may include a second set of flexure joints configured to provide pivotal motion of the first flexure member about the first orientation axis. Likewise, the second flexure member may include third and fourth arms. The third arm may include a third set of flexure joints configured to provide pivotal motion of the second flexure member about the second orientation axis. The fourth arm may include a fourth set of flexure joints configured to provide pivotal motion of the second flexure member about the second orientation axis. Actuators may be coupled to the first and second flexure members. The actuators may be configured to cause pivoting of the first and second flexure members about the first and second orientation axis, respectively, during use. For example, the actuators may be piezoelectric actuators. The first flexure member may include a first opening. The second flexure member may include a second opening. The template support may include a third opening. Each of the first, second and third openings may be configured to allow activating light and sensing light to be directed onto the template during use. The first, second and third openings may be substantially aligned when the first flexure member is coupled to the second flexure member.

Paragraph beginning at page 16, line 3.

Embodiments presented herein generally relate to systems, devices, and related processes of manufacturing small ~~device manufacturing.~~devices. More specifically, embodiments presented herein relate to systems, devices, and related processes of imprint lithography. For example, these embodiments may have application to imprinting very small features on a substrate, such as a semiconductor wafer. It should be understood that these embodiments may also have application to other tasks, for example, the manufacture of cost-effective Micro-Electro-Mechanical Systems (or MEMS). Embodiments may also have application to the manufacture of other kinds of devices including, but not limited to: patterned magnetic media for data storage, micro-optical devices, biological and chemical devices, X-ray optical devices, etc.

Paragraph beginning at page 17, line 10.

Figures 2A ~~thru~~ through 2E illustrate an embodiment of an imprint lithography process, denoted generally as 30. In Figure 2A, template 12 may be orientated in spaced relation to the substrate 20 so that a gap 31 is formed in the space separating template 12 and substrate 20. Surface 14 of template 12 may be treated with a thin layer 13 that lowers the template surface energy and assists in separation of template 12 from substrate 20. The manner of orientation and devices for controlling gap 31 between template 12 and substrate 20 are discussed below. Next, gap 31 may be filled with a substance 40 that conforms to the shape of treated surface 14. Alternately, in an embodiment, substance 40 may be dispensed upon substrate 20 prior to moving template 12 into a desired position relative to substrate 20.

Paragraph beginning at page 17, line 20.

Substance 40 may form an imprinted layer such as imprinted layer 16 shown in Figures 1A and 1 B. Preferably, substance 40 may be a liquid so that it may fill the space of gap 31 rather easily and quickly without the use of high temperatures and the gap can be closed without requiring high pressures. Further details regarding appropriate selections for substance 40 are discussed below.

Paragraph beginning at page 19, line 1.

At step 58, the gap may be closed with fine ~~orientation~~vertical motion of the template ~~about~~with respect to the substrate and the substance. The substance may be cured (step 59) resulting in a hardening of the substance into a form having the features of the template. Next, the template may be separated from the substrate, step 60, resulting in features from the template being imprinted or transferred onto the substrate. Finally, the structure may be etched, step 62, using a preliminary etch to remove residual material and a well-known oxygen etching technique to etch the transfer layer.

Paragraph beginning at page 21, line 24.

In conventional photolithography, the use of optical proximity corrections in the photomasks design is becoming the standard to produce accurate patterns of the designed dimensions. Similar concepts may be applied to micro- and nano-molding or imprint lithography. A substantial difference in imprint lithography processes may be that errors may not be due to diffraction or optical interference but rather due to physical property changes that may occur during processing. These changes may determine the nature or the need for engineered relief corrections in the geometry of the template. A template in which a pattern relief structure is designed to accommodate material changes (such as shrinkage or expansion) during imprinting, similar in concept to optical proximity correction used in optical lithography, may eliminate errors due to these changes in physical properties. By accounting for changes in physical properties, such as volumetric expansion or contraction, relief structure may be adjusted to generate the exact desired replicated feature. For example, Figure 9 depicts an example of an imprint formed without accounting for material property changes 901, and an imprint formed accounting for changes in material properties 902. In certain embodiments, a ~~templete~~template with features having a substantially rectangular profile 904, may be subject to deformations due to material shrinkage during curing. To compensate for such material shrinkage, template features may be provided with an angled profile 905.

Paragraph beginning at page 23, line 6.

A coatings for the template surface may be formed using either a liquid-phase process or a vapor-phase process. In a liquid-phase process, the substrate may be immersed in a solution of precursor and solvent. In a vapor-phase process, a precursor may be delivered via an inert carrier gas. It may be difficult to obtain a purely anhydrous solvent for use in a liquid-phase treatments. Water in the bulk phase during treatment may result in clump deposition, which may adversely affect the final quality or coverage of the coating. In an embodiment of a vapor-phase process, the template may be placed in a vacuum chamber, after which the chamber may be cycle-purged to remove excess water. Some adsorbed water may remain on the surface of the template. A

small amount of water may be needed to complete a surface reaction which forms the coating. It is believed that the reaction may be described by the formula:

$$R\text{-}SiCl_3 + 3H_2O \Rightarrow R\text{-}Si(OH)_3 + 3HCl$$

To facilitate the reaction, the template may be brought to a desired reaction temperature via a temperature-controlled chuck. The precursor may then be fed into the reaction chamber for a prescribed time. Reaction parameters such as template temperature, precursor concentration, flow geometries, etc. may be tailored to the specific precursor and template substrate combination.

Paragraph beginning at page 23, line 25.

As previously mentioned, substance 40 may be a liquid so that it may fill the space of gap 31. For example, substance 40 may be a low viscosity liquid monomer solution. A suitable solution may have a viscosity ranging from about 0.01 cps to about 100 cps (measured at 25 degrees C). Low viscosities are especially desirable for high-resolution (e.g., sub-100nm) structures. <u>Low viscosities may also lead to faster gap closing. Additionally, low viscosities may result in faster liquid filling of the gap area at low pressures</u>. In particular, in the sub-50nm regime, the viscosity of the solution should be at or below about 25 cps, or more preferably below about 5 cps (measured at 25 degrees C). In an embodiment, a suitable solution may include a mixture of 50% by weight n-butyl acrylate and 50% SIA 0210.0 (3-acryoloxypropyltristrimethylsiloxane)silane. To this solution may be added a small percentage of a polymerization initiator (e.g., a photoinitiator). For example, a 3% by weight solution of a 1:1 Irg 819 and Irg 184 and 5% of SIB 1402.0 may be suitable. The viscosity of this mixture is about 1 cps.

Paragraph beginning at page 24, line 17.

In an embodiment, a dispensed volume may typically be less than about 130nl (nano-liter) for a 1inch^2 imprint area. After dispensing, subsequent processes may involve exposing the

template and substrate assembly to a curing agent. Separation of the template from the substrate may leave a transferred image on top of the imprinted surface. The transferred image may lie on a thin layer of remaining exposed material. The remaining layer may be referred to as a "base layer." The base layer should be thin and uniform for a manufacturable imprint. A thin and uniform base layer may assist in the break-through etch needed to eliminate the base layer while retaining the imprinted structure.

Paragraph beginning at page 24, line 24.

Imprint processes may involve high pressures and/or high temperatures applied at the template and substrate interface. However, for the purpose of a manufacturable imprint lithography process including high resolution overlay alignment, high pressures and temperatures should be avoided. Embodiments disclosed herein avoid the need for high temperature by using low viscosity photo-curable fluids. Further, imprinting pressures may be minimized by reducing squeezing force required to spread the fluid across the entire imprinting area. Therefore, for the purpose of fluid based imprint lithography, a fluid dispense process should satisfy the following properties:

6. No air bubble should be trapped between template and substrate;
7. Direct contact between the dispenser tip and substrate should be avoided to minimize particle generation;
8. Pressure required to fill the gap between template and substrate in a timely manner should be minimized;
9. Non-uniform fluid buildup and/or pressure gradients should be minimized to reduce non-uniform localized deformation of template-substrate interface; and
10. Waste of the dispensed fluid should be minimized.

Paragraph beginning at page 25, line 9.

In some embodiments, relative motion between a displacement based fluid dispenser tip and a substrate may be used to form a pattern with substantially continuous lines on an imprinting area. Size of the cross section of the line and the shape of the line may be controlled

by balancing rates of dispensing and relative motion. During the dispensing process, dispenser tips may be fixed near (e.g., on the order of tens of microns) the substrate. Two methods of forming a line pattern are depicted in Figures 10A and 10B. The pattern depicted in Figures 10A and 10B is a sinusoidal pattern; however, other patterns are possible. As depicted in Figures 10A and 10B continue line pattern may be drawn using either~~using~~ a single dispenser tip 1001 or multiple dispenser tips 1002.

Paragraph beginning at page 26, line 11.

Figure 12 illustrates several undesirable fluid patterns or dispensing methods for low viscosity fluids. These dispensing patterns may lead to one or more problems, including: trapping air bubbles, localized deformations, and waste of fluid. For example, dispensing a single drop at the center of the imprinting area 1201, or dispensing irregular lines 1205 may lead to localized deformations of the template and/or substrate. Dispensing several drops 1202, or lines 1206 in a circumferential pattern may lead to trapping of air bubbles. Other dispensing patterns with nearly closed circumferential patterns 1204 may similarly lead to air bubble trapping. Likewise, spraying or random placement of droplets 1203 may lead to trapping of air bubbles. Spin-coating a substrate with a low viscosity fluid may cause a "dewetting" problem due to the thin film instability. Dewetting may lead to formation of numerous small drops of fluid on the substrate, instead of a thin uniform layer of fluid.

Paragraph beginning at page 26, line 23.

In an embodiment, a fluid dispensing method may dispense multiple small drops of liquid that may later be formed into a continuous body as they expand. Figures 13 depicts the case of using five drops of liquid. Here, five drops are used only for the purpose of illustration. Other ~~"open"~~non-bubble forming patterns, such as a sinusoidal line, a 'W', or an 'X' may be implemented using this method. As the template–substrate gap decreases, circular drops 1301 may become thinner and wider causing neighboring drops to merge together 1302. Therefore, even though the initial dispensing may not include a continuous form, the expanding liquid may expel air from the gap between the template and substrate. A pattern effective for use in this

method should be dispensed in such a way that as droplets expand, they do not trap any air between the template and substrate.

Paragraph beginning at page 27, line 4.

Small drops of liquid whose volume may be accurately specified may be dispensed using micro-solenoid valves with a pressure-supporting unit. Another type of the liquid dispensing actuator may include a piezo-actuated dispenser. Advantages of a system with a micro-solenoid valves dispenser as compared to a displacement based fluid dispenser may include faster dispensing time and more accurate volume control. These advantages may be especially desirable for larger size imprints (e.g., several inches across). An embodiment of a system including micro-solenoid valves is depicted in Figure 14. The system may include: fluid container 1401, an inlet tube 1402, an inlet valve 1403, a pump 1404, an outlet valve 1405, a pump controller 1406, a micro-solenoid valve 1407, a micro-solenoid valve controller 1408, an X-Y stage 1409, an X-Y stage controller 1410, and a main computer 1412. A substrate 1411 may be placed on X-Y stage 1409. A suitable micro-valve dispenser system may be available from the Lee Company.

Paragraph beginning at page 27, line 25.

An advantage of providing a well-distributed initial fluid ~~layer,~~layer may be that the orientation error between the template and substrate may be compensated for. This may be due to the hydraulic dynamics of the thin layer of fluid and compliance of the orientation stage. The lower portion of the template may contact the dispensed fluid earlier than other portions of the template. As the gap between the template and substrate gets smaller, the imbalance of reaction forces between the lower and higher portions of the template increases. This imbalance of forces may lead to a correcting motion for the template and substrate, bring them into a substantially parallel relationship.

Paragraph beginning at page 28, line 21.

A second embodiment of an X-Y translation stage is depicted in Fig. 17, and generally referenced by numeral 1700. To provide a similar range of motion to that of X-Y stage 1600, stage 1700 may have a foot print of about 29 inches by 29 inches and a height of about ~~9.5~~15 inches (including a wafer chuck). Stages 1600 and 1700 differ mainly in that additional linkages 1701 are oriented vertically~~, thereby providing additional load bearing support for the translation stage~~.

Paragraph beginning at page 29, line 21.

Figure 18 shows a schematic of portion of a basic linkage 1800. Link 1 ~~1804~~(1804) and link 3 ~~1805~~(1805) may be of the same length. When a moving body 1801 moves along the ~~X axis,~~X-axis, all of the joints in linkage 1800 rotate by the same absolute angle. It should be noted that the motion range may be independent of the length of link 2 ~~1803.~~(1803). Due to kinematic constraints, link 2 ~~1803~~(1803) may remain parallel to a line between joint 1 ~~1806~~(1806) and joint 4 ~~1807.~~(1807). In linkage 1800, the range of motion, l_m, may be given as:

$$l_m = 2\, d_1 \left[\cos(\theta_0 - \alpha_{max}/2) - \cos(\theta_0 + \alpha_{max}/2)\right] = 4\, d_1 \sin(\theta_0)\sin(\alpha_{max}/2), \qquad (5)$$

where, θ_0 is the angle of joint 1 ~~1806~~(1806) when all flexure joints are in their equilibrium conditions, α_{max} is the maximum rotation range of the flexure pivots, and d_1 is the length of links 1 and 3, 1804 and 1805. As shown in Eqn. (5), for given d_1, the motion range is maximized when θ_0 = 90 Degree. Therefore, the link length may be given as:

$$d_1 = l_m/[4\sin(\alpha_{max}/2)] \qquad (6)$$

Therefore, using an α_{max} of 60°, the minimum link length for a 12 inch motion range, is 6 inches.

Paragraph beginning at page 30, line 9.

Figure 19 depicts an embodiment of a basic linkage similar to linkage 1800, but with the addition of two cylindrical disks 1902. A kinematic study shows that if joint 2 1904 and joint 3 1905 of Figure 19 rotate in opposite directions by the same angle, the stage may generate a pure

translational motion along the X axis. By adding cylindrical disks 1902 at flexure joints 2 1904 and 3 1905, the resulting rolling contact may rotate link 1 1908 and link 2 1906 in opposite directions. In an embodiment, no additional joints or bearings may be required since cylindrical discs 1902 may be coupled to links 1908 and 1906. In order to prevent discs 1902 from slipping, an appropriate pre-load may be applied between the two disks. Compared to conventional stages where direct driven mechanisms or bearings may be used, the contact surface here may be relatively small, and relatively easy to maintain. Note that although disks 1902 are not depicted in relation to X-Y stages 1600, and 1700, disks 1902 may be present in some embodiments. Links 1602 and 1601 in Fig. 16 may correspond to links 1908 and 1906 of Fig. 19. Thus, disks 1902 may be present at location 1603 (as well as other locations not visible in the Figure 16). Referring to Figure 17, disks 1902 may be present at location 1702 (as well as other locations not visible in Figure 17).

Paragraph beginning at page 30, line 25.

As the actuation system for either of stages 1600 or 1700, two linear servo motors (as depicted in Fig. 20 and referenced by numeral 2000) may be suitable. One linear servo motor may serve each translation axis. Suitable linear servo motors may be available from the Trilogy Systems Corporation. An advantage of such linear servo motors may be the absence of frictional contact. Another advantage of such linear servo motors may be the fact that they may readily produces actuation forces greater than about 100 pounds. ~~In X-Y stage EE0, load-bearing may be provided by additional linkages 1701.~~ Therefore, actuation components may provide only translational motion control in the X and Y directions. It should be noted that in some embodiments, the actuator of the lower stage might need to be more powerful than the actuator of the upper stage. In some embodiments, laser interferometers may provide a feedback signal to control X and Y positioning of the X-Y stage. It is believed that laser interferometry may provide *nm* level positioning control.

Paragraph beginning at page 32, line 12.

In an embodiment, a fine orientation stage may include one or more actuators. For example, piezo actuators (as described with reference to Figure 46) may be suitable. In such an embodiment, the effective passive compliance of the fine orientation stage coupled with the pre-calibration stage should still be substantially ~~tosional~~ about the two orientation axes. The geometric and material parameters of all the structural and active elements together may contribute to this effective passive stiffness. For instance, piezo actuators may also be compliant in tension and compression. The geometric and material parameters may be synthesized to obtain the desired torsional compliance about the two~~orthogonal~~ orientation axes. A simple approach to this synthesis may be to make the compliance of the actuators along their actuation direction in the fine orientation stage higher than the structural compliances in the rest of the stage system. This may provide passive self-correction capability when a non-parallel template comes into contact with the liquid on the substrate. Further, this compliance should be chosen to allow for ~~rapid correct~~<u>rapidly correcting</u> orientation errors, with minimal or no overshoot. The fine orientation stage may hold the substantially parallel orientation between the template and substrate for sufficiently long period to allow curing of the liquid.

Paragraph beginning at page 33, line 20.

Placement error may generally refer to X-Y positioning errors between a template and substrate (that is, translation along the X and/or Y-axis). Theta error may generally refer to the relative orientation error about Z-axis (that is, rotation about the Z-axis). Magnification error may generally refer to thermal<u>, optical</u> or material induced shrinkage or expansion of the imprinted area as compared to the original patterned area on the template.

Paragraph beginning at page 33, line 26.

In imprint lithography processes, orientation alignment for gap control purposes between a template and substrate corresponding to the angles α and β in Figure 23 may need to be performed frequently if excessive field-to-field surface variations exist on the substrate. In general~~ly~~, it is desirable for the variation across an imprinting area to be smaller than about one-half of the imprinted feature height. If orientation alignments are coupled with the X-Y

positioning of the template and substrate, field-to-field placement error compensations may be necessary. However, embodiments of orientation stages that may perform orientation alignment without inducing placement errors are presented herein.

Paragraph beginning at page 35, line 5.

Figure 24 illustrates the positions of template 2400, substrate 2401, fluid 2403, gap 2405 and overlay error measurement tools 2402. The height of a measuring tool may be adjusted 2406 according to the gap information to acquire two overlay marks on the same imaging plane. In order to fulfill this approach an image storing ~~2403~~2407 device may be required. Additionally, the positioning devices of the template and wafer should be vibrationally isolated from the up and down motions of the measuring device 2402. Further, when scanning motions in X-Y directions between the template and substrate are needed for high resolution overlay alignment, this approach may not produce continuous images of the overlay marks. Therefore, this approach may be adapted for relatively low-resolution overlay alignment schemes for the imprint lithography process.

Paragraph beginning at page 35, line 16.

Figure 25 illustrates an apparatus for focusing two alignment marks from different planes onto a single focal plane. Apparatus 2500 may use the change of focal length resulting from light with distinct wavelengths being used as the illumination sources. Apparatus 2500 may include an image storage device 2503, and illumination source (not shown), and a focusing device 2505. Light with distinct wavelengths may be generated either by using individual light sources or by using a single broad band light source and inserting optical band-pass filters between the imaging plane and the alignment marks. Depending on the gap between the template 2501 and substrate 2502, a different set of two wavelengths may be selected to adjust the focal lengths. Under each illumination, each overlay mark may produce two images on the imaging plane as depicted in Figure 26. A first image 2601 may be a clearly focused image. A second image 2602 may be an out-of-focus image. In order to eliminate each out-of-focus image, several methods may be used.

Paragraph beginning at page 35, line 29.

In a first method, under illumination with a first wavelength of light, two images may be received by an imaging array (e.g., a CCD array). Images which may be received are depicted in Figure 26 and generally referenced by numeral 2604. Image 2602 may correspond to an overlay alignment mark on the substrate. Image 2601 may correspond to an overlay alignment mark on the template. When image 2602 is focused, image 2601 may be out of focus, and visa-versa. In an embodiment, an image processing technique may be used to erase geometric data corresponding to pixels associated with image 2602. Thus, the out of focus image of the substrate mark may be eliminated, leaving image ~~2603.~~2601. Using the same procedure and a second wavelength of light, image 2605 and 2606 may be formed on the imaging array. The procedure may eliminate out of focus image 2606. Thus image 2605 may remain. The two remaining focused images 2601 and 2605 may then be combined onto a single imaging plane 2603 for making overlay error measurements.

Paragraph beginning at page 37, line 5.

Placement errors may be compensated for using capacitance sensors or laser interferometers to locate the substrate on a high resolution X-Y stage, and high resolution motion of these X-Y stages. In an embodiment where orientation alignments between the template and substrate are independent from X-Y motions, placement error may need to be compensated for only once for an entire substrate (e.g., a semiconductor wafer). Such a method may be referred to as a "global overlay." If orientation alignments between the template and substrate are coupled with X-Y motions and excessive local orientation variations exist on the substrate, X-Y position change of the template may be compensated for using capacitance sensors and/or laser interferometers. Such a method may be referred to as a "field-to-field overlay." Figures 28 and 29 depict suitable sensor implementations. Figure 28 depicts an embodiment of a capacitance sensing system. A capacitance sensing system may include capacitance sensors 2801, a conductive coating 2802, on a template 2803. Thus, by sensing differences in capacitance, the location of template 2803 may be determined. Similarly, Figure 29 depicts an embodiment of a

laser interferometer system including reflective coating 2901, laser signal 2902, received 2903. Laser signals received by receiver 2903 may be used to determine the location of template 2904.

Paragraph beginning at page 37, line 21.

The magnification error, if any exists, may be compensated for by carefully controlling the temperature of the substrate and the template. Using the difference of the thermal expansion properties of the substrate and template, the size of pre-existing patterned areas on the substrate may be adjusted to that of a new template. However, it is believed that the magnification error may be much smaller in magnitude than placement error or theta error when an imprint lithography process is conducted at room temperature and low pressures. Magnification error may also be compensated for by using stress-based methods as disclosed herein.

Paragraph beginning at page 37, line 28.

The theta error may be compensated for using a theta stage that has been widely used for photolithography processes. Theta error may be compensated for by using two separate alignment marks that are separated by a sufficiently large distance to provide a high resolution theta error estimate. The theta error may be compensated for when the template is positioned a few microns or less apart from the ~~substrate. Therefore, no shearing of existing patterns may occur.~~substrate prior to curing the liquid.

Paragraph beginning at page 38, line 17.

Two methods are disclosed to overcome the problem of recognizing template overlay mark in the presence of the liquid. A first method uses an accurate liquid dispensing system along with high-resolution gap controlling stages. Suitable liquid dispensing systems and the gap controlling stages are disclosed herein. For the purpose of illustration, three steps of an overlay alignment are depicted in Figure 30. The locations of the overlay marks and the patterns of the fluid depicted in Figure 30 are only for the purpose of illustration and should not be construed in a limiting sense. Various other overlay marks, overlay mark locations, and/or liquid

dispense patterns are also possible. First, in step 3001, a liquid 3003 may be dispensed onto substrate 3002. Then, in step 3004, using the high-resolution orientation stage, the gap between template 3005 and substrate 3002 may be carefully controlled so that the dispensed fluid 3003 does not fill the gap between the template and substrate completely. It is believed that at step 3004, the gap may be only slightly larger than the final imprinting gap. Since most of the gap is filled with the fluid, overlay correction can be performed as if the gap were completely filled with the fluid. The overlay marks may be placed such that the liquid does not cover them in this first position. Upon the completion of the overlay correction, the gap may be closed to a final imprinting gap (step 3006). This may enable spreading of the liquid into the remaining imprint area, including covering the alignment marks. Since the gap change between steps 3004 and 3006 may be very small (e.g., about 10nm), the gap closing motion is unlikely to cause any significant overlay error.

Paragraph beginning at page 43, line 1.

In an embodiment, a gap measurement process may be based the combination of the broad-band interferometry and Fast Fourier Transform (FFT). Several applications in current industry utilized various curve fitting techniques for the broad-band interferometry to measure a single layer film thickness. However, it is expected that such techniques may not provide real time gap measurements, especially in the case of multi-layer films, for imprint lithography processes. In order to overcome such problems, first the reflective indexes may be digitized in wavenumber domain, between $1/\lambda_{high}$ and $1/\lambda_{low}$. Then, the digitized data may be processed using a FFT algorithm. This novel approach may yield a clear peak of the FFT signal that accurately corresponds to the measured gap. For the case of two layers, the FFT signal may yield~~to~~ two clear peaks that are linearly related to the thickness of each layer.

Paragraph beginning at page 44, line 4.

FFT is an established technique in which the frequency of a discrete signal may be calculated in a computationally efficient way. Thus, this technique may be useful for in-situ analysis and real-time applications. Figure 34 depicts an embodiment of a process flow of film

thickness or gap, measurement via a FFT process of a reflectivity signal. For multi-layer films with distinct reflective indexes, locations of peaks in FFT process may correspond to linear combinations of each film thickness. For example, a two-layer film may lead to two distinct peak locations in a FFT analysis. Figure 35 depicts a method of determining the thickness of two films based on two peak locations.

Paragraph beginning at page 46, line 4.

Figure 38 depicts a schematic of the gap measurement described here. Probes 3801 may also be used in an inclined configuration, such as depicted in Figure 39. If more than three probes are used, the gap measurement accuracy may be improved by using the redundant information. For simplicity's sake, the ensuing description assumes the use of three probes. The step size, $h_{s\cancel{-AC2}}$, is magnified for the purpose of illustration. The average gap at the patterned area, h_p, may be given as:

$$h_p = [\,(h_1 + h_2 + h_3)/3\,] - h_s, \tag{9}$$

When the positions of the probes are known ((x_i, y_i), where x and y axes are on the substrate surface), the relative orientation of the template with respect to the substrate may be expressed as an unit vector (**n**) that is normal to the template surface with respect to a frame whose x-y axes lie on the top surface of the substrate.

$$\mathbf{n} = \mathbf{r} / \|\mathbf{r}\|, \tag{10}$$

where, $\mathbf{r} = [(x_3, y_3, h_3) - (x_1, y_1, h_1)] \times [(x_2, y_2, h_2) - (x_1, y_1, h_1)]$. Perfect orientation alignment between two flats may be achieved when $\mathbf{n} = (0\ 0\ 1)^T$, or $h_1 = h_2 = h_3$.

Paragraph beginning at page 46, line 19.

Measured gaps and orientations may be used as feedback information to imprinting actuators. The size of the measuring broad-band interferometric beam may be as small as about $75\mu m$. For a practical imprint lithography process, it may be desirable to minimize the clear area used only to measure the gap since no pattern can be etched into~~at~~ the clear area. Further, blockage of the curing agent due to the presence of measurement tool should~~to~~ be minimized.

Paragraph beginning at page 47, line 16.

With reference to Figures 42A and 42B, therein are depicted embodiments of the first and second flexure members, 126 and 128, respectively, in more detail. Specifically, the first flexure member 126 may include a plurality of flexure joints 160 coupled to corresponding rigid bodies 164, 166. Flexure joints 160 and rigid bodies 164, and 166 may form part of arms 172, 174 extending from a frame 170. Flexure frame 170 may have an opening 182, which may permit the penetration of a curing agent (e.g., UV light) <u>and a sensing agent (e.g., for gap sensing and/or overlay alignment sensing)</u> to reach the template 150 when held in support 130. In some embodiments, four (4) flexure joints 160 may provide motion of the flexure member 126 about a first orientation axis 180. Frame 170 of first flexure member 126 may provide a coupling mechanism for joining with second flexure member 128 as illustrated in Figure 43.

Paragraph beginning at page 47, line 27.

Likewise, second flexure member 128 may include a pair of arms 202, 204 extending from a frame 206. Arms 202 and 204 may include flexure joints 162 and corresponding rigid bodies 208, 210. Rigid bodies 208 and 210 may be adapted to cause motion of flexure member 128 about a second orientation axis 200. A template support 130 may be integrated with frame 206 of the second flexure member 128. Like frame 182, frame 206 may have an opening 212 permitting a curing agent <u>and a sensing agent</u> to reach template 150 which may be held by support 130.

Paragraph beginning at page 49, line 12.

Mounting a second flexure component orthogonally onto the first one (as depicted in Figure 43) may provide a device with two decoupled orientation axes that are orthogonal to each other and lie on the template-substrate interface 254. The flexure components may be adapted to have openings to allow a curing agent (e.g., UV light) <u>and a sensing agent (e.g., for gap sensing and/or overlay alignment sensing)</u> to pass through the template 150.

Paragraph beginning at page 50, line 1.

In an embodiment, ~~an~~ flexure member having active compliance may be provided. For example, Figure 46 depicts a flexure member, denoted generally as 400, including piezo actuators. Flexure member 400 may be combined with a second flexure member to form an active orientation stage. Flexure member 400 may generate pure tilting motions with no lateral motions at the template-substrate interface. Using such a flexure member, a single overlay alignment step may allow the imprinting of a layer on an entire semiconductor wafer. This is in contrast to overlay alignment with coupled motions between the orientation and lateral motions. Such overlay alignment steps may lead to disturbances in X-Y alignment, and therefore may require a complicated field-to-field overlay control loop to ensure proper alignment.

Paragraph beginning at page 50, line 17.

With imprint lithography, it may be desirable to maintain a uniform gap between two nearly flat surfaces (i.e., the template and the substrate). Template 150 may be made from optical flat glass~~using electron beam lithography~~ to ensure that it is substantially flat on the bottom. The template may be patterned using electron beam lithography. The substrate (e.g., a semiconductor wafer), however, may exhibit a "potato chip" effect resulting in micron-scale variations on its topography. Vacuum chuck 478 (as shown in Figure 47), may eliminate variations across a surface of the substrate that may occur during imprinting.

Paragraph beginning at page 50, line 24.

Vacuum chuck 478 may serve two primary purposes. First, vacuum chuck 478 may be utilized to hold the substrate in place during imprinting and to ensure that the substrate stays flat during the imprinting process. Additionally, vacuum chuck 478 may ensure that no particles are present on the back of the substrate during processing. This may be especially important to imprint lithography, as back-side particles may create flatness problems that ruin the device and decrease production yields. Figure 48A and 48 B illustrate variations of a vacuum chuck suitable for these purposes according to two embodiments.